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HAULROAD DESIGN AT HIGHVALE MINE

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HAULROAD DESIGN AT HIGHVALE MINE

by

R. Whipple* and R.J. Kolada**

ABSTRACT

Truck haulage at surface mines represents a major portion of operating costs. A significant factor of these costs is rolling resistance. From an operator's viewpoint, rolling resistance is dependent on the quality of haulageway construction and maintenance.

This report summarizes the trafficability study commissioned by TransAlta Utilities in 1983 for the Highvale Mine. The study is comprised of field and laboratory testing of soil materials, haul road design using available materials, the mine operator's current construction methods, recommendations for construction, and rolling resistance testing.

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CONCEPTION DES CHEMINS DE SERVICE À LA MINE HIGHVALE

par

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RÉSUMÉ

Le transport par camion représente une partie considérable des coûts d'opération d'une exploitation minière à ciel ouvert. Un des facteurs importants contribuant à ces coûts est la résistance au roulage. Du point de vue de l'exploitant, la résistance au roulage dépend de la qualité de la construction et de l'entretien des chemins de service.

Le présent rapport résume les résultats d'une étude sur la praticabilité des chemins de service de la mine Highvale, demandée par la TransAlta Utilities en 1983. L'étude comprend des essais sur le terrain et en laboratoire sur les matériaux du sol, la conception des chemins de service réalisée à l'aide de matériaux disponibles, les méthodes de construction actuelles utilisées par l'exploitant de la mine, les recommandations ayant trait à la construction et enfin, des essais de résistance au roulage.

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1.0 INTRODUCTION

The Surface Mining Laboratory of CANMET with Davis Engineering has commissioned the construction of a vehicle capable of measuring the rolling resistance of mine haulage roads. In conjunction with this research program it will be necessary to investigate the criteria by which mine haulage roads are designed and tested in order to examine the correlation between how the construction of roads affects rolling resistance.

In 1983 Highvale Mine commissioned a trafficability study. The purpose was to define haul road design parameters for mine site personnel to use in the construction of temporary and permanent roads for coal and overburden transportation.

The study is comprised of three main parts, field testing of soil samples, haul road design and construction, and rolling resistance testing of a rear end dump truck. Previous data from other studies done during the period from 1979 through 1981 is also included.

2.0 MATERIAL TESTING

Much time was devoted to soil testing. Some tests were done at the mine site while other samples were collected for laboratory tests. There were four groups of samples:

1. Mine spoil containing clay, shale and coal fragments;
2. In-situ bedrock comprised of silt, and weathered siltstone or sandstone;
3. Till which contains silty clay and fragments of coal and shale;
4. Undisturbed till samples composed of silty clay and weathered shale.

Samples from the previous study include in-situ sandstone, mine spoil and glacial till.

2.1 FIELD TESTS

In-situ density was measured by the sand cone method and nuclear densometer. Moisture content was determined by the nuclear densometer. Cone penetration tests were performed with the hope of correlating the results with California Bearing Ratio Test data. The testing was done on highwall benches, spoil piles and in pits.

2.2 LABORATORY TESTS

Laboratory analysis determined the following material properties:

Oven-dried moisture content,
Atterberg Limits and subsequent soil classification,
Proctor Compaction testing to determine the optimum moisture content and maximum dry density,
unsoaked California Bearing Ratios at dry and optimum moisture content,
California Bearing Ratios in the soaked condition, and
grain size distribution plots.

The laboratory procedure for determination of the Atterberg Limits was presumably done in accordance with standard procedures.

Proctor compaction tests were performed on samples combined from two or three locations. The samples were remoulded and either the Standard Proctor Compaction Test (ASTM D698), or the Modified Proctor Compaction Test (ASTM D1557) were performed. The local maxima of this curve defines the maximum dry density and the optimum moisture content. The Modified Proctor compaction test uses a larger hammer and greater free fall distance. The maximum dry density is greater and the optimum moisture content lesser than the Standard Proctor test.

2.3 DISCUSSION OF TEST RESULTS

For one sample of mine spoil containing silty clay and coal and shale fragments, a difference of 216 percent exists between the oven dried and nuclear densometer moisture content methods. This is the worst case. Statistical analysis of the data is precluded by the lack of precision of the results. The variance of the sample results is greater than the corresponding mean value in most cases. A table

is attached to this report shoving the rav data values for the field CBR measurements, oven dried and nuclear densometer measurements of moisture content along vith their corresponding mean and variance calculations for each group. The last column is the difference calculations.

In all cases but one, the moisture content determined by the nuclear densometer is higher than the oven dried method. Some of the discrepancy between the two methods can be attributed to different soil properties. For instance, oven drying would burn off water and coal volatiles resulting in erroneously high moisture contents. The nuclear densometer has limitations, too. Its operation slovs fast neutrons and this rate of deceleration is proportional to the number of hydrogen atoms present. Unless calibration compensated for organic soils, moisture content determinations would be erroneously high since hydrogen is contained in vater and other hydrocarbon substances [1].

Previous testing of in-situ sandstone resulted in assumed CBR values of 100%. A six ton reaction load was insufficient to cause penetration of the piston.

The laboratory results also varrant discussion.

At vet and dry of optimum moisture contents CBR tests were performed. In the report these samples were tested in the "unsoaked" condition. The only conclusion which can be made at this time from Figures 1 through 20 (Appendix D of the report) is that the saturated CBR is less than the "unsoaked" CBR at the optimum moisture content.

Similar results were realized from a previous campaign. The in-situ sandstone specimens in the the "soaked" condition resulted in CBR values which range from 6.9 to 31.2%.

3.0 CORRELATION OF RESULTS

Attempts have been made to find relationships between the CBR values and moisture content, plasticity index, dry density and cone penetrometer readings.

The CBR value decreases as moisture content increases for the field samples. For the laboratory "unsoaked" tests, the CBR increases until the optimum moisture content is reached, and decreases

thereafter. The "soaked" samples had decreasing values throughout the range of moisture content tested.

The saturated CBR varies inversely with the plasticity index. An insufficient number of data points are available for regression analysis. Because this relationship is valid only at optimum moisture content, its use as a field testing method is limited because it would be inconvenient.

The "unsoaked" CBR is a function of the dry density of the sample, but the range of values is too great to predict any finite relationship. One exception is the sandstone specimens where CBR values vary almost infinitely for a small change in the dry density.

4.0 HAUL ROAD DESIGN

There are five types of in-situ material presented in the report, and reproduced in the following table:

MATERIAL	CBR %	No. TESTS
Clay Till Spoil	2.9 - 7.3	9
Clay Till, undisturbed	2.7 - 7.9	4
Siltstone, weathered	5.2 - 14.8	6
Sandstone	100.0	10
Mine Waste (Shale)	4.6 - 22.4	6

4.1 SUBGRADE MATERIAL

Material such as muskeg, peat or soft soils found in swampy or low-lying areas are not recommended for the underlying subgrade. Spoil which has been recently dumped is also not suitable.

With one exception, the above material classifications do not reappear in a subsequent table which assigns a design and CBR value to one of six classes of material. The table is reproduced here.

MATERIAL	CBR %	REMARKS
Mine Spoil	3	loose dumped
Shale, Till	5	disturbed shale bedrock
Siltstone, sandstone	15	disturbed bedrock
Sandstone	80 *	hard undisturbed bedrock
Shale, siltstone	40	hard undisturbed bedrock
Siltstone	50	hard undisturbed bedrock

*this classification was probably the ten in-situ samples of sandstone with assumed CBR=100%.

The consultants report suggests that prior to any permanent haul road construction, CBR tests of the subgrade should be performed. The term "permanent" is defined as any period longer than six months.

4.2 SUBBASE MATERIAL

The subbase is that material which is placed on the subgrade and compacted. It is ideally three layers; a well distributed, clean, inorganic soil; a thinner layer of coarse crushed rock; and a layer of fine crushed rock [2]. The report recommends any material, except organic materials and wet clays for temporary haul roads. Some materials would require drying prior to placement and compaction. But for permanent roadway construction, only sandstone and pit gravel are deemed suitable. These materials would minimize maintenance because they are effective in preventing frost heaves and differential settlement.

The recommended subbase materials are reproduced here, in this table from the report:

MATERIAL	DESIGN CBR VALUE (%)
compacted mine spoil	15.0
compacted shale, dry till	15.0
compacted siltstone	30.0
compacted sandstone	50.0
compacted gravel	80.0.

4.3 ROAD BED DESIGN

The reference literature used by the consulting firm for road bed design is the USBM Information Circular 8758, "Design of Surface Mine Haulage Roads - A Manual". In this handbook, a graph relating CBR

values of subgrade and compacted materials to required subbase thickness for wheel load has been drawn. An example details the procedure for determining the thickness of each layer of subbase material.

The mine operator, however, uses a similar thickness (25 cm.) of lesser quality pit run gravel for the road surface layer. The underlying layer is composed of clayey mine spoil or mine partings. After compaction the road surface is hard and sealed, protecting the bentonitic subbase. It is recommended that fly ash be added to the surface layer of the subbase to act as binder for the gravel.

Comments about the creation of design charts for dual wheel loads state that for a TEREX 33-15B hauler which has a single wheel configuration, an approximation for dual tires can be made by adding 20% to the single wheel load. For the coal hauler, a single wheel load is 43500 kg. Therefore, the dual wheel approximation would be 43500 kilograms plus 20%, or 52200 kilograms. The CBR versus subbase thickness graph would be drawn for this newly approximated load. The report claims the approximation is valid because the variability of the CBR value for a particular soil can be as much as 30 percent.

5.0 HAUL ROAD CONSTRUCTION

Haulage construction procedures are not detailed in the report. Instead, a reference is made to a manual of design codes written by the consultants for Highvale Mine. A few brief points are made, however. Organic surface material should be removed and the subgrade rolled prior to placement of the subbase. The subbase material is to be spread in layers not exceeding 30 cm in thickness. Sandstone is recommended as the best subbase material because its moisture content is dry of optimum. Main haul roads will require attention to control moisture content. To achieve at least 95% Modified Proctor, the moisture content should be measured, preferrably with a nuclear densometer. Calibration of the instrument is to be done by the sand cone or Washington Balloon methods. Finally, the road surface should be at least 1.3 metres above the surrounding land grade with a surface slope of 4 percent to provide adequate drainage.

6.0 ROLLING RESISTANCE TESTING

The field testing of the rolling resistance of different haul roads appears to be a separate entity from the previous sections of the report. In fact, no references are made to previous reports or internal standards.

A Caterpillar 769C rear-end dump truck (31.8 tonne payload) was towed at various locations by a Caterpillar 16G motor grader. In all but one test, the truck was loaded. Segments of haul roads with a slight, but constant uphill grade were chosen for the tests. The 50,000 lb. dynamometer was read as soon as steady state motion had been achieved. A surveying level, rod and chain were used to determine road grades.

The range of results of the ten tests are typical of what one might expect for an operating mine. Permanent haulage from the generating plants to the various pit areas were constructed by contractors. On a permanent haul road near the Keephills Generating Plant the rolling resistance was determined to be 2.0%. A gravel access road built by the mine operator has a rolling resistance of 2.7 percent. The rolling resistance was measured at 3.9% on a hard packed clay-gravel access road near Pit 03. A slight increase in the rolling resistance was measured (RR=4.1%) for a hard packed clay road. On in-situ overburden (after topsoil and subsoil stripping) two rolling resistance values are 4.0 and 4.5% for an unloaded and loaded truck, respectively. At a different location the rolling resistance on similar material was 6.7%. The measured rolling resistance was 4.4% on an overburden stockpile. Another stockpile composed of regolith and muskeg had 8.3% rolling resistance.

7.0 CONCLUSIONS

The trafficability study done at the Highvale Mine determined soil properties for various on site materials as well as measuring some actual rolling resistance data.

The Washington balloon or sand cone tests are considered standard methods for determining in-situ density. The nuclear

densometer is a field instrument whose calibration is dependent on the type of soil. Its calibration must be done with respect to the standard methods.

Laboratory procedures follow ASTM or other applicable standards. Compaction tests were performed on remoulded samples to approximate field conditions and determine optimum moisture content maximum dry density.

Because the mean value of a group of data samples is less than the variance in most cases, a statistical or regression analysis is not warranted. In addition, the population (number) of the group is too small. Some physical relationships can only be discussed on a qualitative basis.

For the purposes of haul road design, tested materials are grouped into five CBR classifications. The various types of subgrade one may encounter on the property are assigned CBR design values. Compaction of the subgrade material is recommended prior to placement of the subbase. The subbase materials are grouped into five classes and given CBR values for the compacted state.

Recommendations by the consultants for haul design are based on reference literature from the United States Bureau of Mines. To circumvent lengthy and complex calculations for determininug dual wheel load, an approximation of +20% to single wheel load will suffice for plotting CBR versus subbase thickness graphs.

Moisture content is the main parameter for haulageway construction. Its measurement will indicate the degree of compaction. At least 95% Modified Proctor must be achieved.

The rolling resistance results ranged from 2.0 to 8.3 percent. From this study, rolling resistance is influenced by primarily the construction method and asserted quality control, and the type of material used in road building.

REFERENCES:

1. Bekker,M.G., Introduction to Terrain-Vehicle Systems, The University of Michigan Press, Ann Arbor, Michigan, 1969.

2. Anonymous, Haul Road Design for Off-Highway Dump Trucks, Komatsu Ltd. Industrial Application Materials AP-47, Japan.

3. Karafiath,L.L. and Novatzki,E.A., Soil Mechanics for Off-Road Vehicle Engineering, Trans-Tech Publications Series on Rock and Soil Mechanics, Vol.2, No.5, Clausthal, Germany, 1978.

APPENDIX A

THE CALIFORNIA BEARING RATIO TEST

The California Bearing Ratio Test was developed by California highway engineers to improve the design of flexible asphalt roadways. It is used infrequently for the classification of soils in off-highway disciplines [3]. It is a comparison of the load carrying capacity of the tested soil material to a standard sample of crushed stone which has an assigned CBR value of 100 percent.

To perform the CBR test, a clean site is chosen and levelled with sand. Surcharge weights are placed on the sand to approximate the actual load {FOOTNOTE}. A steady load is applied to cause the penetration of the piston at a rate of 0.05 inches per minute.
The deflection of the proving ring is recorded at various depths of penetration to about 0.5 inches. Knowing the piston diameter, the bearing value can be computed in pounds per square inch. The value is compared to the standard load, 1000 psi or 1500 psi depending on the "rezeroing effect".

The graph of bearing value versus penetration is typically curvilinear. A tangent is drawn from the curve to intersect the absicca. Where the tangent line intersects the x-axis, a "new" origin is placed. The translated 0.1 and 0.2 penetration bearing values are read from the plot. The CBR values at the 0.1 and 0.2 penetrations should be similar; the 0.2 inch reading is used for the comparison. If 0.1 penetration value is less than the 0.2 value, the latter is considered correct. Should the 0.1 CBR value be greater, the test must be redone.

Moisture content is measured after the test at the point of penetration. Density is measured at least 6 inches from the test location. Successive tests should be spaced at least 8 inches apart in plastic soils and 16 inches in coarse, granular soil.

This procedure is described in more detail in the manual; "Operation and Service Instructions", Soiltest,Inc.,Evanston,Illinois,U.S.A., and distributed by Hoskin Scientific (Western) Ltd.,Vancouver,B.C.

TABLE 1

FIELD CBR			MOISTURE CONTENT						
			Oven			Nuclear			Diff'ce
Data	Mean	Var.	Data	Mean	Var.	Data	Mean	Var.	Data
15.0			20.3 %			20.0 %			- 1.5 %
12.0			13.8			22.3			61.6
9.8			9.6			17.2			79.2
22.4			5.5			17.4			216.
4.6			24.2			23.7			2.07
8.1	12.0	38.4	58.3	15.6	43.3	22.0	22.0	28.3	58.3
9.9			18.5			23.0			24.3
9.7			21.3			23.3			9.39
14 8			20.0			23.8			19.0
5.2			23.0			26.1			13.5
10.2			17 6			24.0			36.4
9.2	9.83	9.34	18.5	19.8	4.15	24.5	24.1	1.22	32.4
2.9			24.3			36.8			51.4
4.7			16.0			29.8			86.2
4.6			21.7			32.8			51.1
5.4			15.0			21.2			41.3
7.3			15.6			18.5			18.6
3.9			16.6			22.8			37.4
4.7			19.8			33.1			67.2
4.1			28.8			35.6			23.6
3.7	4.59	1.24	26.7	20.5	26.7	42.8	30.4	65.0	60.3
3.9			35.2			45.9			30.4
7.9			23.7			37.3			57.4
3.7			30.5			45.0			47.5
2.7	4.55	2.29	25.1	28.6	27.8	40.3	42.1	16.2	60.6